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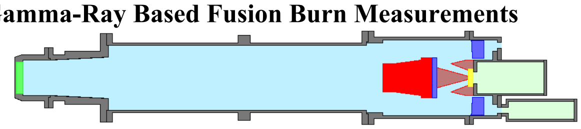
Gamma-Ray Based Fusion Burn Measurements



A gas Cerenkov detector is being built for use on the OMEGA laser and NIF to record high-energy gamma-rays emitted during DT gas burn. An igniting NIF capsule would produce an ~20ps FWHM signal, while a failing capsule burn history may have ~100ps FWHM. Time resolving this signal is a challenge. Our concept relies on measuring the 16.7 MeV gamma rays produced by the rare DT fusion reaction with He5 as an intermediary, instead of gammas produced by spectrally or time-of-flight broadened 14 MeV neutrons. The detector first converts gamma-rays to high energy electrons through Compton conversion and pair production in a Be block (green). Cerenkov light is emitted by those electrons with energies greater than 12 MeV when traveling through 27 psi CO_2 gas (light blue) with an index of refraction set to 1.00083. This threshold energy dramatically reduces extraneous background signals. The critical conversion processes (gamma to electron and electron to visible light) involve small angle processes, which take place throughout the volume of the detector leading to variable path lengths from target to recorder. Two mirrors (dark blue) form a Cassegrain telescope which images the Cerenkov light onto a microchannel-plate photomultiplier (located in the light green chamber). Tungsten baffles (red) reduce the number of stray electrons striking the gas cell window (yellow) while allowing most of the Cerenkov light to pass. Low energy electrons striking the window would produce extraneous Cerenkov light. .The light collection system has been designed such that the inherent time resolution of the detector is ~7 ps. Initial experiments will use a microchannel-plate photomultiplier (180 ps FWHM) to detect the Cerenkov light. Simply observation of the 16.7 MeV gamma is the primary objective for this fiscal year. If the September run at OMEGA is successful as a proof-of-principle for the gas Cerenkov burn history measurement, then the emphasis next year will be on developing a recording system capable of utilizing the bandwidth of the gas cell.

Detector design, sensitivity and background studies were possible using the Integrated Tiger Series Monte Carlo code modified to include Cerenkov production, optical transition radiation, and full time history of all particles. The results of this code were iterated with the ASAP optics code to optimize the light collection system, while providing radiation shielding and stray light baffles. The detector can be mounted in any OMEGA TIM (Target Instrumentation Module) or NIF DIM.

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Neutron Imaging with Pinhole and Penumbral Apertures

In collaboration with the CEA-DIF (France), Los Alamos is developing neutron imaging techniques for the National Ignition Facility (NIF). The CEA pioneered the use of penumbral imaging on the Phebus laser, and will continue its development on Omega. Pinhole imaging has been used in both countries' nuclear weapons programs for decades. In the past Los Alamos has fielded the highest resolution pinhole system, achieving ~ 90 µm resolution with a 50 µm diameter pinhole, and will concentrate on a pinhole system for Omega.

Both neutron and penumbral imaging require an "optical" element that is idealized to be opaque to neutrons except possibly for a small opening. Since neutron attenuation in dense, high Z material, like gold or tungsten is only about 0.3 / cm, the actual "optical element" is thick, typically 10-20 cm long in the line of sight, and only ~1x 1cm perpendicular to it. . Rather than a hole in a plate, the aperture is biconical, coming to a minimum diameter in the center (which may even be 0!). This taper angle determines the field of view and, to a large extent, the resolution. Figure 1 shows the design of a pinhole for Omega. It will be built from two gold coated tungsten pieces pinned together, each scribed with a tapered groove, producing a tapered opening with a square rather than circular cross section. The pinhole has the advantage that its image directly reflects the source, as does a pinhole camera, but the image is formed from only those few neutrons passing through a small aperture. The penumbral technique uses a much larger aperture (~600 µm), and deconvolves the image from the edge of the shadow (penumbra) cast by the source. The technique forms the image from many more neutrons but is more sensitive to noise.

The CEA has developed a multi-element plastic scintillator bundle and optical recording system to observe the magnified penumbral and pinhole images 800cm from the target. The scintillator element size of 1.5mm square limits the current system resolution to ~30 µm. In the future deuterated plastic will allow smaller 0.5 mm square elements and higher resolution. The neutron aperture and the alignment apparatus instrument are mounted in a TIM cart designed by the CEA and modified by Los Alamos for the pinhole assembly.

On the Omega laser the techniques will be compared using images derived from both techniques on similar directly driven targets. Figure 2 shows the radial profiles of round neutron images we expect from DT filled glass microballoons and plastic shells directly irradiated with 32kJ in 1ns pulses. Our goals for this year are to record resolutions of ~30 microns, while testing alignment and aperture fabrication techniques. Next fiscal year we will aim for 20 µm, along the path to a NIF system with 4µm resolution.

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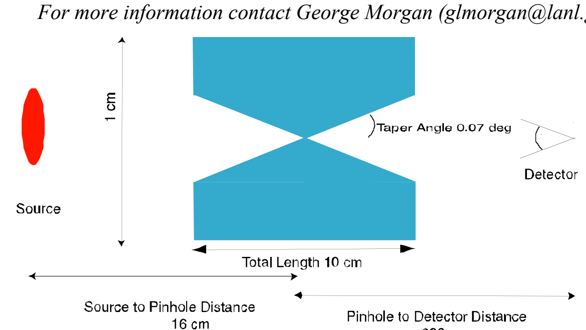

Figure 1. Omega pinhole system design.

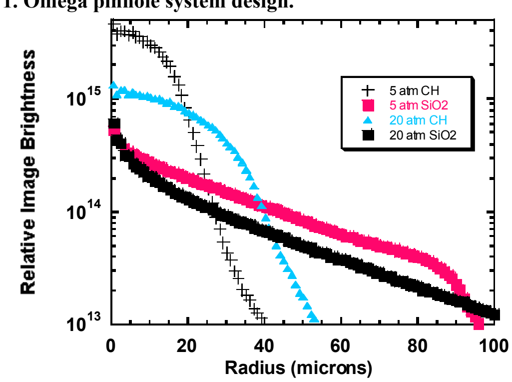

Figure 2. Calculated neutron image profiles for CH and glass microballoons with 5 and 20 atm DT.

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